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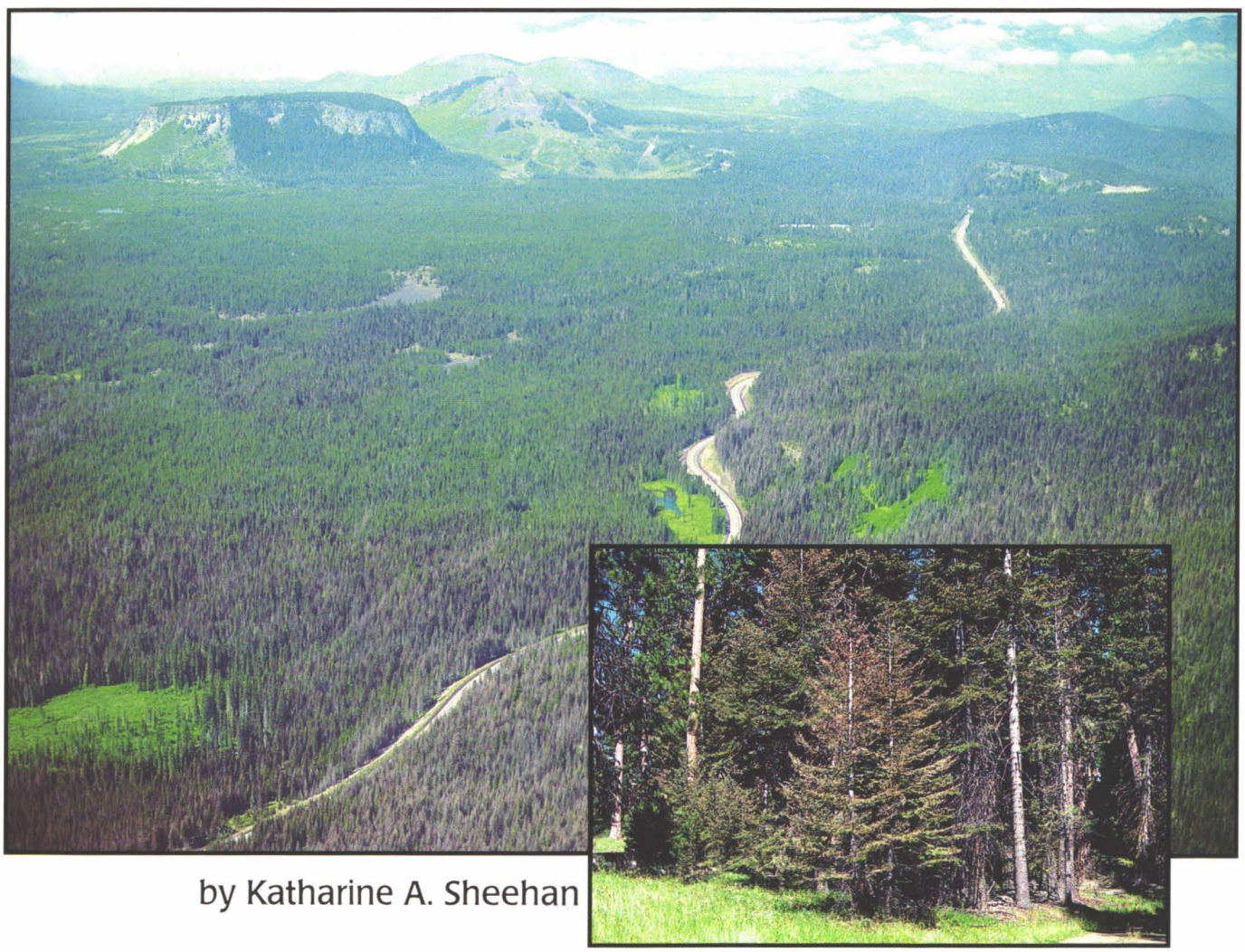
Defoliation by Western Spruce Budworm in Oregon and Washington from 1980 through 1994



by Katharine A. Sheehan

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Defoliation by Western Spruce Budworm in Oregon and Washington from 1980 through 1994

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U.S. Department of Agriculture
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Portland, Oregon

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Defoliation caused by western spruce budworm, *Choristoneura occidentalis* Freeman, has been recorded annually during aerial surveys. This paper summarizes those observations and displays them on a series of maps. The locations and characteristics of aerially applied insecticide treatments conducted against western spruce budworm are also summarized.

keywords: western spruce budworm, *Choristoneura occidentalis*, defoliation, insecticides, suppression projects

Defoliation by Western Spruce Budworm in Oregon and Washington from 1980 through 1994

Introduction

Western spruce budworm, *Choristoneura occidentalis* Freeman (Lepidoptera: Tortricidae), is widely regarded as one of the most economically important defoliators of western coniferous forests (Johnson and Denton 1975, Furniss and Carolin 1977, Fellin and Dewey 1982). Budworm larvae feed primarily on developing buds and new foliage, and repeated heavy defoliation may lead to changes in foliage chemistry, reduced diameter and height growth, increased topkill, increased mortality, and reductions in seed and cone production (Van Sickle 1987).

This native insect is found from British Columbia and Alberta, Canada to Arizona and New Mexico, and its range generally matches that of its principal host, Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) (Harvey 1985). Other major hosts for western spruce budworm are white fir (*Abies concolor* (Gord. & Glend.) Lindl.), grand fir (*A. grandis* (Dougl.) Lindl.), subalpine fir (*A. lasiocarpa* (Hook.) Nutt.), Engelmann spruce (*Picea engelmannii* Parry), and western larch (*Larix occidentalis* Nutt.), though larvae will occasionally feed on many other western conifers (Fellin and Dewey 1982). Budworm ecology and effects on trees are summarized in Sanders and others (1985) and Brookes and others (1987). An extensive bibliography is also available (McKnight and others 1988).

Dolph (1980) published maps showing annual defoliation by both western spruce budworm and modoc budworm (*C. retiniana* Walsingham) for 1947 through 1979. Maps and tables describing aerial suppression projects aimed at western spruce budworm during that period were also included (Dolph 1980). New outbreaks of western spruce budworm have occurred since 1979, primarily in the Blue Mountains of northeastern Oregon and southeastern Washington and on the eastern slopes of the Cascade Mountains in both states. This publication documents the extent and severity of defoliation by western spruce budworm from 1980 through 1994; aerially applied insecticide treatments conducted during that period are also reported.

Methods

Aerial Sketchmap Surveys

Aerial sketchmap surveys have been conducted annually in Oregon and Washington since 1947 through a cooperative project involving the Oregon Department of Forestry, the Washington Department of Natural Resources, and the USDA-Forest Service. In most years, public and private forested lands are surveyed during July through early September. A grid pattern is flown over most areas. Two observers (each sketching a 2-mile swath on their side of the plane) mark the location of insect and disease activity

onto 1:126,720 (Oregon) or 1:100,000 (Washington) maps. Causal agents and severity are also recorded for each polygon. The accuracy and precision of sketchmaps can be affected by local weather conditions, regional fire activity, tree species composition, and observer. The timing of the aerial survey relative to budworm development varies from year to year and may also affect sketchmap accuracy. General aerial sketchmapping methods are described in Klein and others (1983), and information specific to sketchmapping in Oregon and Washington from 1980 through 1994 was provided by David R. Bridgwater and Timothy J. McConnell (personal communication).

For 1980 through 1984, the severity of defoliation by western spruce budworm was rated as either light, moderate, or heavy (see table 1). In practice, during 1980-1984 these severity codes were used to show relative intensity of current defoliation without regard to top-killing or tree mortality; that is, light = defoliation is just visible, medium = foliage appears fairly red, and heavy = foliage is very red (T.J. McConnell, personal communication). In 1985, severity was not rated for most areas; for display purposes, unrated areas are shown as light defoliation in figure 2 and Appendix A. From 1986 through 1993, a new four-class system based on cumulative defoliation effects was used to rate defoliation severity in Oregon (see table 1), while the previous three-class system was used for most of Washington. Starting in 1994, the four-class system has been used in both states. The defoliation severity ratings are intended to reflect the cumulative effects of several consecutive years of defoliation. Defoliation is mapped and rated only in areas where budworm is currently active.

Aerially Applied Insecticide Treatments

From 1980 through 1993 a total of 59 different aerially applied insecticide treatments aimed at either western spruce budworm or both budworm and Douglas-fir tussock moth were identified (Hadfield 1992, 1994, [n.d.]; Howes and Wallesz [n.d.]; Ragenovich 1988; Skyler and others 1990). Nearly 2,198,000 acres were treated during this period, though some areas were treated more than once (Sheehan 1996). Maps suitable for digitizing could not be located for 10 projects covering approximately 32,570 acres (1.5% of the total acres treated).

Geographic Information System (GIS) Data

Since 1988, aerial sketchmaps have been scanned or digitized during the year of observation for most forested lands in Oregon and Washington. Sketchmaps for previous years are stored on microfilm. As part of a separate study on the effects of insecticide treatments on subsequent defoliation by budworm (Sheehan 1996), paper copies of sketchmaps were produced from the microfilm records and then digitized.

Boundaries of insecticide treatments conducted by the USDA-Forest Service were either digitized from paper copies of project maps (1980-89, 1991-92) or obtained as electronic files from the operational staffs that conducted the projects (1990 and 1993). For projects conducted by private industry, boundaries were digitized from paper copies of project maps except for the project conducted by Boise Cascade in 1992, which was obtained as an electronic file.

Table 1. Systems used to classify defoliation severity in Oregon and Washington (1980-1994) [a].

3 class system	4 class system
Light - defoliation of current year foliage is present	**1** - defoliation of current year foliage is visible from the air
Moderate - Defoliation of current year foliage and apparent top-killing are present	**2** - defoliation of current year foliage is visible and some bare tops are present
Heavy - Defoliation of current year foliage and apparent tree killing are present	**3** - defoliation of current year foliage is visible and many bare tops are present
	4 - defoliation of current year foliage is visible and most crowns are bare; virtually no foliage is left

[a] The 3-class system was used in both Oregon and Washington from 1980-84, and in most of Washington from 1986-93. The 4-class system was used in Oregon and southeastern Washington from 1986-93, and in both states since 1994.

Electronic versions of both sketchmaps and spray project boundaries are available in several formats. For further information, contact the GIS Coordinator, Forest Insects and Diseases group, USDA-Forest Service Pacific Northwest Region, P.O. Box 3623, Portland, OR 97208-3623 (currently: Julie Johnson, 503-326-6698).

Results

Aerial observations of defoliation by western spruce budworm in Oregon and Washington for 1980 through 1994 are summarized in Figure 2 and Appendix A. Characteristics of aerially applied insecticide treatments conducted during this period are described in Appendix B. Appendix C shows the annual distribution of defoliation by western spruce budworm by year for 1980 through 1994, and Appendix D shows the locations of insecticide treatments conducted during this period.

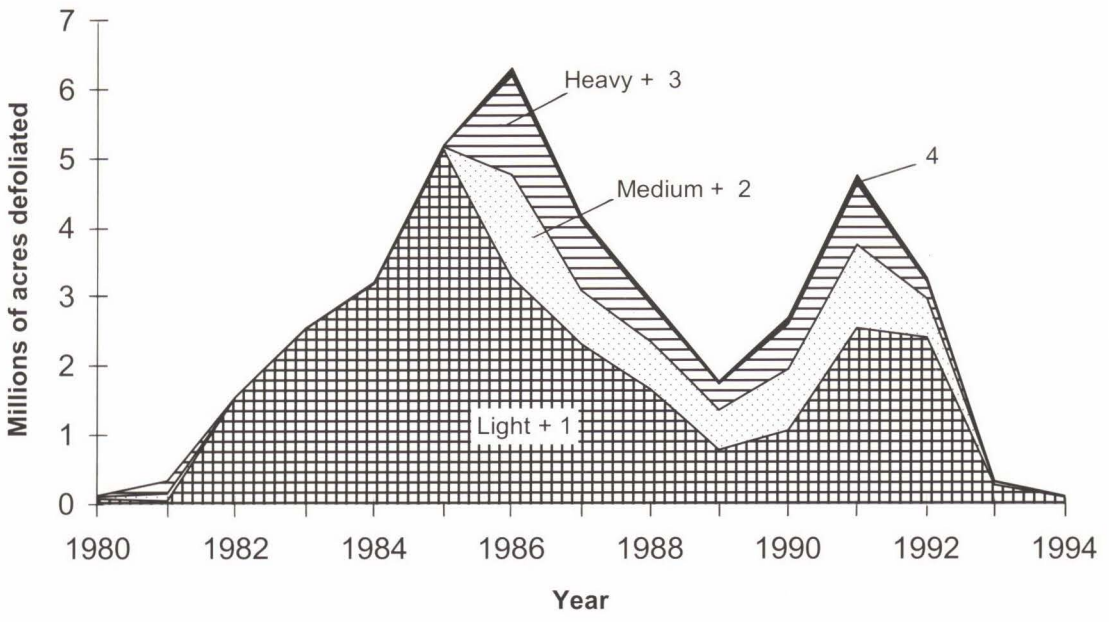

Figure 2. Acres defoliated by western spruce budworm in Oregon and Washington by severity class (as recorded during annual aerial surveys; see Table 1 for definitions of severity classes).

Discussion

From 1980 through 1994, most of the defoliation caused by western spruce budworm occurred in the Blue Mountains of northeastern Oregon and southwestern Washington, on the eastside of the Cascade Mountains from the Yakama Indian Reservation south to the Deschutes National Forest, or on or near the Okanogan National Forest in northcentral Washington. Peak annual defoliation was much more extensive during this period (up to 6.3 million acres defoliated in 1988) than was reported by Dolph (1980) for either the 1947-1950 outbreak in Oregon (less than 3 million acres defoliated in 1950) or the 1972-1979 outbreak in Washington (less than 1.5 million acres defoliated in 1977).

Defoliation severity is difficult to evaluate because of apparent inconsistencies in severity classes used from year to year and/or from state to state. A majority of the defoliated area was rated as heavy in 1981, which would not be expected after only one or two years of defoliation. From 1982 through 1984 nearly all defoliated areas were rated as light, and severity was not rated in 1985 (though unrated areas are shown as light defoliation for display in figure 2). Finally, two different systems (four classes in Oregon and a small portion of Washington, and three classes in the rest of Washington) were used to classify severity or damage from 1986 through 1993.

Carbaryl (1982 and 1983) and *Bacillus thuringiensis kurstaki* (1984 through 1994) were the active ingredients that were most commonly used in aerially applied insecticide treatments. The effects of these insecticide treatments on subsequent defoliation by

western spruce budworm are described by Sheehan (1996). For a limited number of projects, effects of insecticide treatments on diameter growth, topkill, and mortality are reported by Torgersen and others (1995) and Powell (1994).

The period of extensive visible defoliation reported here lasted about 10 to 11 years in the Blue Mountains and eastside of the Cascades in Oregon, and 8 to 9 years in central and northcentral Washington. Previous aerial survey records for this region showed extensive visible defoliation lasting for 8 to 14 years (Dolph 1980), and a range of 13 to 17 years was documented in dendrochronological studies conducted in the northern Blue Mountains (Swetnam and others 1995).

Most general areas that had previously been defoliated (according to Dolph [1980]) were again defoliated starting in the early- to mid-1980's. The interval between outbreaks (when little or no defoliation was recorded) ranged from 22 to 38+ years in Oregon and central Washington. In northcentral Washingon, part of the area that had been defoliated in the 1970's (in or near the Okanogan National Forest) was again defoliated after only 5 years had elapsed, while the remaining area (in or near the Wenatchee National Forest) has not been defoliated again through 1994. Since the early 1900's, Swetnam and others (1995) report that the interval between outbreaks has ranged from 6 to 21 years (average = 13.7 years) in the northern Blue Mountains.

Those reported intervals should be considered very conservative, however, because since the early 1900s forest management practices in the eastside forests of Oregon and Washington -- primarily fire suppression and removal of non-host species such as pines -- have greatly increased the occurrence of multi-storied forests with substantial portions of true firs and Douglas-fir (Hessburg and others 1994, Oliver and others 1994). These forests are highly susceptible to defoliation by western spruce budworm (Wickman 1992), and the interval between outbreaks is likely to decrease (Swetnam and others 1995). Given those conservative intervals reported by Swetnam and others (1995), the next period of extensive visible defoliation in areas that have historically supported budworm populations would be expected to start sometime before 2001 in or near the Wenatchee National Forest in northcentral Washington and between 1998 and 2013 in Oregon and the rest of Washington.

Acknowledgments

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Appendix A

Acres defoliated by western spruce budworm and acres treated with aerially applied insecticides from 1980 through 1994

	Acres defoliated by severity class[a]							Total acres	Acres
Year	Light	Medium	Heavy	Class 1	Class 2	Class 3	Class 4	defoliated	treated
1980	87,090	22,916	15,997	0	0	0	0	126,003	0
1981	50,572	106,422	182,164	0	0	0	0	339,158	0
1982	1,566,391	51	0	0	0	0	0	1,566,442	199,398
1983	2,543,409	5,578	770	0	0	0	0	2,549,757	620,527
1984	3,192,334	14,146	7,778	0	0	0	0	3,214,258	800
1985	5,127,520	42,303	22,786	0	0	0	0	5,192,609	40,821
1986	258,298	35,843	6,341	3,028,159	1,449,997	1,428,302	105,889	6,312,829	13,202
1987	356,498	26,994	6,734	1,965,036	747,165	997,338	73,139	4,172,904	158,979
1988	210,088	25,419	1,219	1,462,705	660,863	540,595	68,492	2,969,381	674,952
1989	279,905	32,241	20,417	511,478	540,646	357,307	32,183	1,774,177	14,412
1990	262,940	44,737	25,436	809,225	838,154	624,653	94,652	2,699,797	71,677
1991	896,809	54,603	33,603	1,650,159	1,154,841	842,726	120,503	4,753,244	114,048
1992	1,211,403	23,020	21,660	1,198,729	539,951	222,234	54,063	3,271,060	219,214
1993	232,273	11,484	0	49,508	31,889	6,441	0	331,595	66,792
1994	0	0	0	108,484	9,382	2,198	2,922	122,986	0
							Totals:	39,396,200	2,194,822

[a] see table 1 for description of severity classes

Source: electronic data on file with Forest Insects and Diseases, Natural Resources, Pacific Northwest Region, Forest Service, U.S. Department of Agriculture, P.O. Box 3623, Portland, OR 97208-3623

Appendix B

Characteristics of insecticide treatments applied aerially in Oregon and Washington from 1980 through 1994

Appendix B -- Characteristics of insecticide treatments applied aerially in Oregon and Washington from 1980 through 1993

Year	Project[1]	Total acres treated[2]	Active ingredient	Insecticide	Dilution	Oz/ac
1980	(Daterman)*	200	pheromone	---	---	---
1982	Baldy	32,660	carbaryl	Sevin-4-oil	diesel	64
1982	Madison	61,950	carbaryl	Sevin-4-oil	diesel	64
1982	Middle Fork-A	59,400	carbaryl	Sevin-4-oil	diesel	64
1982	Middle Fork-B	9,423	acephate	Orthene	water	128
1982	Opal	35,970	carbaryl	Sevin-4-oil	diesel	64
1983	Aldrich	118,800	carbaryl	Sevin-4-oil	diesel	64
1983	Butte	6,094	carbaryl	Sevin-4-oil	diesel	64
1983	Logan	107,800	carbaryl	Sevin-4-oil	diesel	64
1983	King	16,990	carbaryl	Sevin-4-oil	diesel	64
1983	Matlock	88,880	carbaryl	Sevin-4-oil	diesel	64
1983	Miller Prairie	132,700	carbaryl	Sevin-4-oil	diesel	64
1983	Putney	40,270	carbaryl	Sevin-4-oil	diesel	64
1983	Pearson	25,270	carbaryl	Sevin-4-oil	diesel	64
1983	Pogue Pt-A	14,120	carbaryl	Sevin-4-oil	diesel	64
1983	Pogue Pt-B	11,120	mexacarbate	Zectran	diesel	128
1983	Pogue Pt-C	12,280	Bt	Thuricide 32LV	water	96
1983	PA	16,900	carbaryl	Sevin-4-oil	diesel	64
1983	Rudio Mtn	23,980	carbaryl	Sevin-4-oil	diesel	64
1983	Snow	5,377	carbaryl	Sevin-4-oil	diesel	64
1984	Prineville *	800	Bt	Thuricide 32LV/ San415 32LV	water	96
1985	Rail	9,660	Bt	Dipel 8L	none	24
1985	Scotty	10,390	Bt	Thuricide 32LV	none	32
1985	Crooked-A	12,110	Bt	Thuricide 32LV	water	96
1985	Crooked-B	863	Bt	Thuricide 32LV	water	64
1985	Burnt Cabin	7,796	Bt	Dipel 8L	water	48
1986	Boise Casc. *	13,200	carbaryl	Sevin-4-oil	diesel	64
1987	Dixie	18,150	Bt	Dipel 6AF/Thur.48LV	water	96
1987	Flat	47,790	Bt	Dipel 6L/Thur.48LV	water	96
1987	Canyon	22,830	Bt	Dipel 6L/Thur.48LV	water	96
1987	Lost Cabin	23,760	Bt	Dipel 6L/Thur.48LV	water	96
1987	Starr	333	Bt	Dipel 6L	water	96
1987	Rimrock	45,760	Bt	Thuricide 48LV	water	96
1987	Burns *	360	Bt	Dipel 6L	varied	43-96

Dose/ac	Aircraft type	Budworm density[3] pre-treatment	Budworm density[3] post-treatment	Agency	Estimated cost[4]	Estimated cost/ac[5]	Source[6]
---	fixed	n.a.[7]	n.a.	USFS	n.a.	n.a.	S1
16 oz	rotary	20.0±2.1	1.6±.3	USFS	$333,300	$11.40	H1,R2
16 oz	rotary	14.2±1.8	1.3±.3	USFS	$632,200	$11.40	H1, R2
16 oz	rotary	21.4±2.2	1.9±.4	USFS	$606,200	$11.40	H1,R2
8 oz	rotary	24.8±2.8	3.9±.7	USFS	$96,170	$11.40	H1,R2
16 oz	rotary	10.2±1.3	0.7±.2	USFS	$367,100	$11.40	H1,R2
16 oz	rotary	19.1	1.7	USFS	$929,100	$9.25	B1,S3
16 oz	rotary	37.5	0.9	USFS	$47,650	$9.25	B1,S3
16 oz	rotary	17.9	0.8	USFS	$842,600	$9.25	B1,S3
16 oz	rotary	16.7	1.3	USFS	$132,900	$9.25	B1,S3
16 oz	rotary	34.6	1.9	USFS	$695,000	$9.25	B1,S3
16 oz	rotary	31.7	0.9	USFS	$1,037,000	$9.25	B1,S3
16 oz	rotary	25.6	1.5	USFS	$314,900	$9.25	B1,S3
16 oz	rotary	24.1	3.1	USFS	$197,600	$9.25	B1,S3
16 oz	rotary	21.6	2.7	USFS	$110,400	$9.25	B1,S3
2 oz	rotary	26.1	2.9	USFS	$86,980	$9.25	B1,S3
12 biu	rotary	10.8	3.3	USFS	$96,020	$9.25	B1,S3
16 oz	rotary	19.7	0.3	USFS	$132,100	$9.25	B1,S3
16 oz	rotary	16.5	1.5	USFS	$187,500	$9.25	B1,S3
16 oz	rotary	17.2	1.3	USFS	$42,050	$9.25	B1,S3
20-30 biu	rotary	18.5±3.0	1.5±0.5	USFS	n.a.	n.a.	R1
12 biu	fixed	10.53±0.68	1.17±0.18	USFS	$114,400	$11.80	R1,R2
12 biu	fixed	9.91±0.75	1.12±0.21	USFS	$123,100	$11.80	R1,R2
12 biu	rotary	10.31±0.72	0.64±0.12	USFS	$143,500	$11.80	R1,R2
15 biu	rotary	8.4±0.70	0.40±0.18	USFS	$10,220	$11.80	R1,R2
12 biu	rotary	11.03±0.92	0.97±0.12	USFS	$92,340	$11.80	R1,R2
16 oz	rotary	n.a.		private	n.a.	n.a.	S1
12 biu	rotary	11.28±1.04[e]	1.79±0.24	USFS	$286,700	$19.50	R1,R2,S2
12 biu	both	6.28±0.64[e]	1.11±1.19	USFS	$755,200	$19.50	R1,R2,S2
12 biu	rotary	5.83±0.32[e]	3.12±0.71	USFS	$360,600	$18.25	R1,R2,S2
12 biu	both	4.03±0.32[e]	2.18±0.26	USFS	$375,500	$18.25	R1,R2,S2
12 biu	rotary	5.30±3.55[e]	4.58±0.58	USFS	$5,350	$18.25	R1,R2,S2
12 biu	rotary	5.9±0.82[e]	0.89±0.10	USFS	$853,500	$19.33	R1,R2,S2
30-40 biu	rotary	6.03	3.23	USFS	n.a.	n.a.	R1

Year	Project[1]	Total acres treated[2]	Active ingredient	Insecticide	Dilution	Oz/ac
1988	Meacham-T	42,860	Bt	Thuricide 48LV	none	64
1988	Meacham-D	34,130	Bt	Dipel 6AF	none	64
1988	Tollgate	97,126	Bt	Thuricide 32LV	none	64
1988	Starkey	3,608	Bt	Thuricide 32LV	none	64
1988	Barlow-D	115,500	Bt	Dipel 6L	none	43
1988	Barlow-T	25,822	Bt	Thuricide 32LV	none	64
1988	Warm Springs	185,000	Bt	Thuricide 32LV	none	64
1988	Dalles	116,600	Bt	Thuricide 32LV	none	64
1988	Hood River-S	35,330	carbaryl	Sevin-4-oil	diesel	64
1988	Hood River-B	6,137	Bt	Thuricide 32LV	water	96
1988	Sisters (WI) *	300	Bt	Foray 48B	none	43
1988	Tollgate (BC) *	12,500	carbaryl	Sevin-4-oil	diesel	64
1989	High Rock	7,595	Bt	Dipel 6L	none	43
1989	Halfway	4,217	Bt	Foray 48B	none	43-64
1989	Boise Casc. *	2,000	carbaryl	Sevin-4-oil	diesel	64
1989	Enterprise *	600	Bt	Condor AD	water	97
1990	Yakima	71,680	Bt	Thuricide 48LV	none	43
1991	Hells Canyon	15,270	Bt	Thuricide 48LV	none	43
1991	Pine	78,650	Bt	Thuricide 48LV	none	43
1991	Catherine Cr.	20,130	Bt	Thuricide 48LV	none	43
1992	Boise Casc.	29,220	carbaryl	Sevin-4-oil	diesel	64
1992	Indian Creek	20,690	Bt	Thuricide 48LV	none	64
1992	Mill	5,985	Bt	Thuricide 48LV	none	64
1992	Morgan	27,510	Bt	Thuricide 48LV	none	64
1992	Kuhn-Chesn.	42,940	Bt	Thuricide 48LV	none	64
1992	Suttle Lake-S	5,434	carbaryl	Sevin-4-oil	diesel	64
1992	Suttle Lake-T	511	Bt	Thuricide 48LV	n.a.	n.a.
1992	Mt.Emily	25,910	Bt	Thuricide 48LV	none	64
1992	Thimbleberry	33,870	Bt	Thuricide 48LV	none	64
1992	Meacham	27,150	Bt	Thuricide 48LV	none	64
1993	Warm Springs	64,180	Bt	Dipel 6AF	none	64
1993	Hood River Co.*	2,530	carbaryl	Sevin-4-oil	diesel	64
1993	(Grimble) *	80	Bt	Thuricide	water	96
	Total	2,195,000				

Dose/ac	Aircraft type	Budworm density[3] pre-treatment	Budworm density[3] post-treatment	Agency	Estimated cost[4]	Estimated cost/ac[5]	Source[6]
16 biu	rotary	19.3±0.9	1.5±0.5	USFS	$767,000	$27.10	B2,A1
16 biu	rotary	17.8±0.9	1.8±0.2	USFS	$797,200	$27.10	B2,A1
16 biu	both	7.22±1.08[e]	0.62±0.12	USFS	n.a.	n.a.	B2,A2
16 biu	both	6.50±1.37[e]	1.42±0.39	USFS	n.a.	n.a.	B2,A2
16 biu	both	9.19±0.99[e]	0.38±0.05	USFS	n.a.	n.a.	B2
16 biu	both	n.a.	0.57±0.08	USFS	n.a.	n.a.	B2
16 biu	rotary	n.a.	0.71±0.35	USFS	n.a.	n.a.	B2
16 biu	both	n.a.	2.40±0.36	USFS	n.a.	n.a.	B2
16 oz	rotary	19.2±17.1[e]	0.5±0.4	private	$390,300	$11.26	S1,O
12 biu	rotary	20.8±14.8[e]	2.7±2.0	private	$67,800	$11.26	S1,O
16 biu	rotary	12.48±0.66	1.50±0.21	private	n.a.	n.a.	S1,B3
16 oz	rotary	n.a.	n.a.	private	n.a.	n.a.	S1
16 biu	rotary	15.2[e]	$6	USFS	n.a.	n.a.	S1,A5
16 biu	rotary	24.8	4.2	USFS	$457,500	$108.50	S1,H6
16 oz	rotary	n.a.	n.a.	private	n.a.	n.a.	S1
3 doses	rotary	n.a.	n.a.	USFS	n.a.	n.a.	S1
16 biu	both	27.0±3.5[e]	2.33±0.55	USFS	$1,088,000	$15.35	H2
16 biu	both	12.5	n.a.	USFS	n.a.	n.a.	A4,A5
16 biu	both	9.9	n.a.	USFS	n.a.	n.a.	A4,A5
16 biu	both	20.9	n.a.	USFS	n.a.	n.a.	A4,A5
16 oz		16	0.25	private	n.a.	n.a.	G
24 biu	both	8.2	1.1	USFS	$333,400	$16.88	H3
24 biu	both	18.6	3.4	USFS	$100,600	$16.88	H3
24 biu	both	7.6	0.8	USFS	$720,100	$16.56	H4
24 biu	both	9.7	1.3	USFS	$442,700	$16.56	H4
16 oz	n.a.	7.26±.58	.31±.08	private	n.a.	n.a.	A3
24 biu	n.a.	6.69±.59	.91±.18	private	n.a.	n.a.	A3
24 biu	both	10.7	1.9	USFS	$428,500	$16.88	H3
24 biu	both	12.8	2.7	USFS	$569,300	$16.88	H3
24 biu	both	12.1	2.1	USFS	$532,200	$16.88	H3
24 biu	rotary	4.5	0.7	USFS	$862,000	$13.43	H5
16 oz	n.a.	n.a.	n.a.	private	n.a.	n.a.	
16 biu	n.a.	n.a.	n.a.	USFS	n.a.	n.a.	

Appendix B, continued:

Footnotes:

[1] * = maps suitable for digitizing are not available

[2] Numbers are rounded to show a maximum of 4 significant digits. Source is electronic files on file with Forest Insects and Diseases, Natural Resources, Pacific Northwest Region, USDA Forest Service, P.O. Box 3623, Portland, OR 97208-3623.

[3] The pre-treatment column actually shows either pre-treatment samples (taken within a few days prior to treatment) or early larval samples (taken about the time of budbreak). The early larval samples are marked by a superscript "e". Post-treatment samples were taken 14 days after treatment. Densities shown are number of larvae per 45-cm midcrown branch tip. Densities shown for 1982 were originally reported as number of larvae per square meter of foliage, and were converted to number of larvae per 45-cm branch tip by assuming that the average branch width was 45 cm. When densities were available for separate units within a project, average unit densities were weighted by unit size (in acres) to calculate average density for the project.

[4] When cost information was available only for several projects combined, costs were prorated to individual projects based on actual project size (in acres). Costs include both application and administrative costs and are rounded to show a maximum of 4 significant digits.

[5] For 1982 through 1988 , these estimates are based on originally reported acres treated, which was calculated as (total amount of insecticide applied) / (amount of insecticide applied per acre).

[6] Sources: A1 = USDA (1988a), A2 = USDA (1988b), A3 = Anonymous [n.d.]a, A4 = Anonymous [n.d.]b, A5 = Anonymous [n.d.]c, B1 = Bridgwater [n.d.]a, B2 = Bridgwater [n.d.]b, B3 = Buffam and Buffam (1988), G = Goodall (1992), H1 = Hostetler [n.d.], H2= Hadfield (1992), H3 = Hadfield [n.d.], H4 = Howes and Wallesz [n.d.], H5 = Hadfield (1994), H6 = Hadfield and Hostetler [n.d.], O = Overhulser [n.d.], R1 = Ragenovich (1988), R2 = Ragenovich [n.d.], S1 = Skyler and others (1990), S2 = Scott [n.d.], S3 = Sirmon (1983)

[7] n.a. = not available

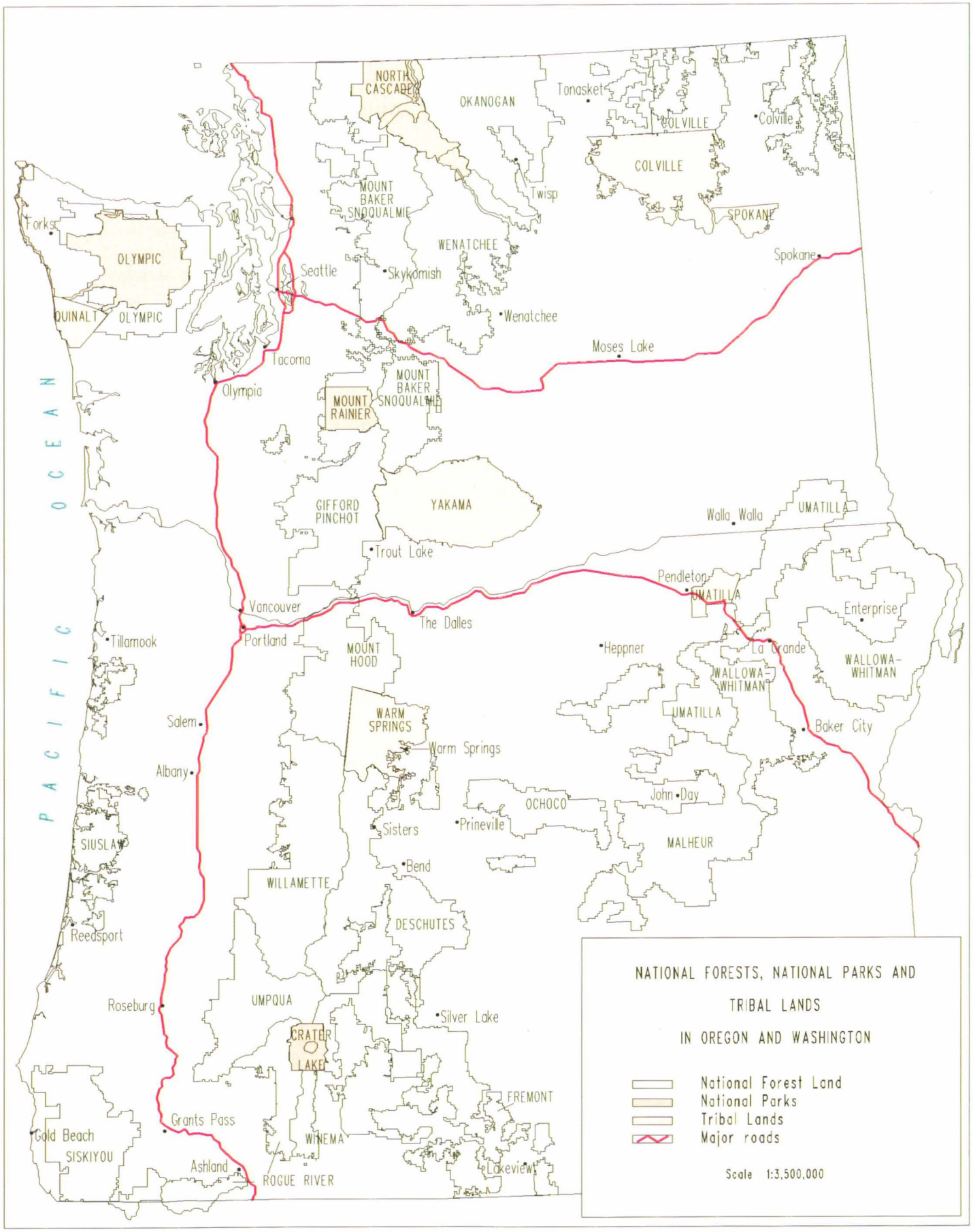
Appendix C

Location of defoliation by western spruce budworm as recorded annually during aerial surveys, and location of aerially applied insecticide treatments (1980 - 1994)

Map 1 is a reference map showing names of National Forests, National Parks, and Indian Reservations. The following maps show defoliation caused by western spruce budworm for the years 1980 (map 2) through 1994 (map 16) as recorded during aerial surveys.

Maps 16 and 17 show the locations of insecticide treatments aimed at western spruce budworm that were conducted from 1982 through 1993.

Source: electronic files on file with Forest Insects and Diseases, Natural Resources, Pacific Northwest Region, Forest Service, U.S. Department of Agriculture, P.O. Box 3623, Portland, OR 97208.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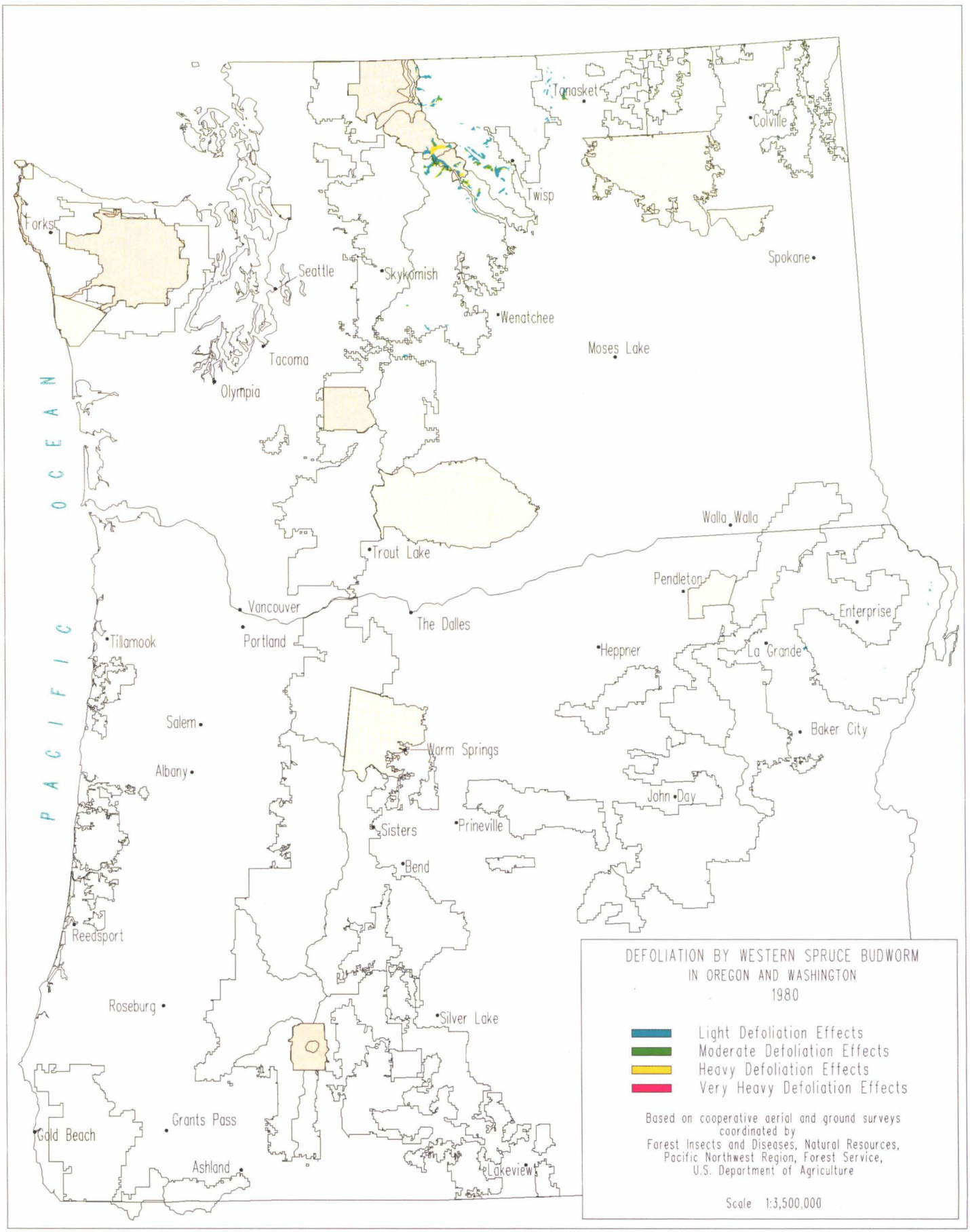
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DEFOLIATION BY WESTERN SPRUCE BUDWORM
IN OREGON AND WASHINGTON
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Light Defoliation Effects
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Very Heavy Defoliation Effects
Based on cooperative aerial and ground surveys
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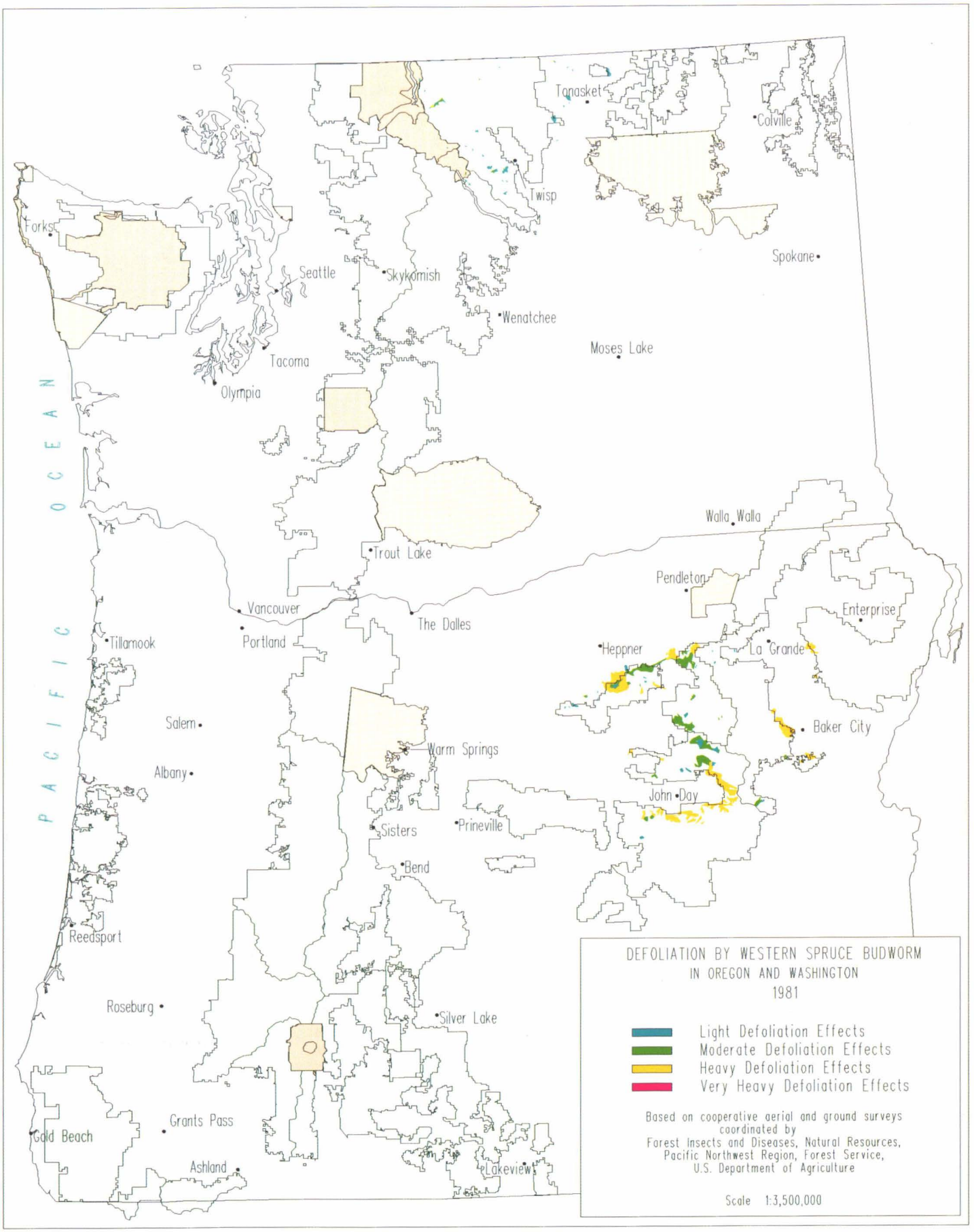
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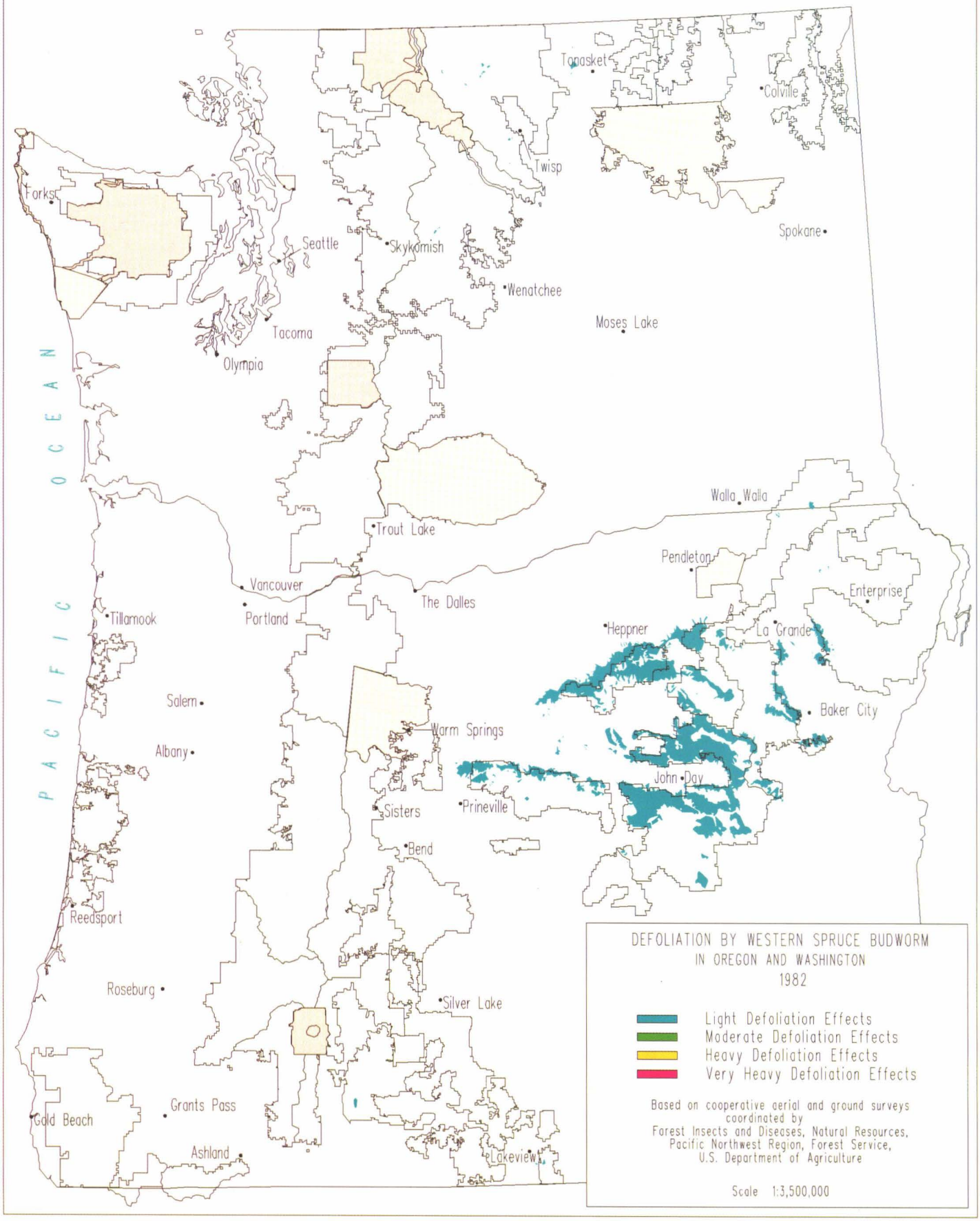
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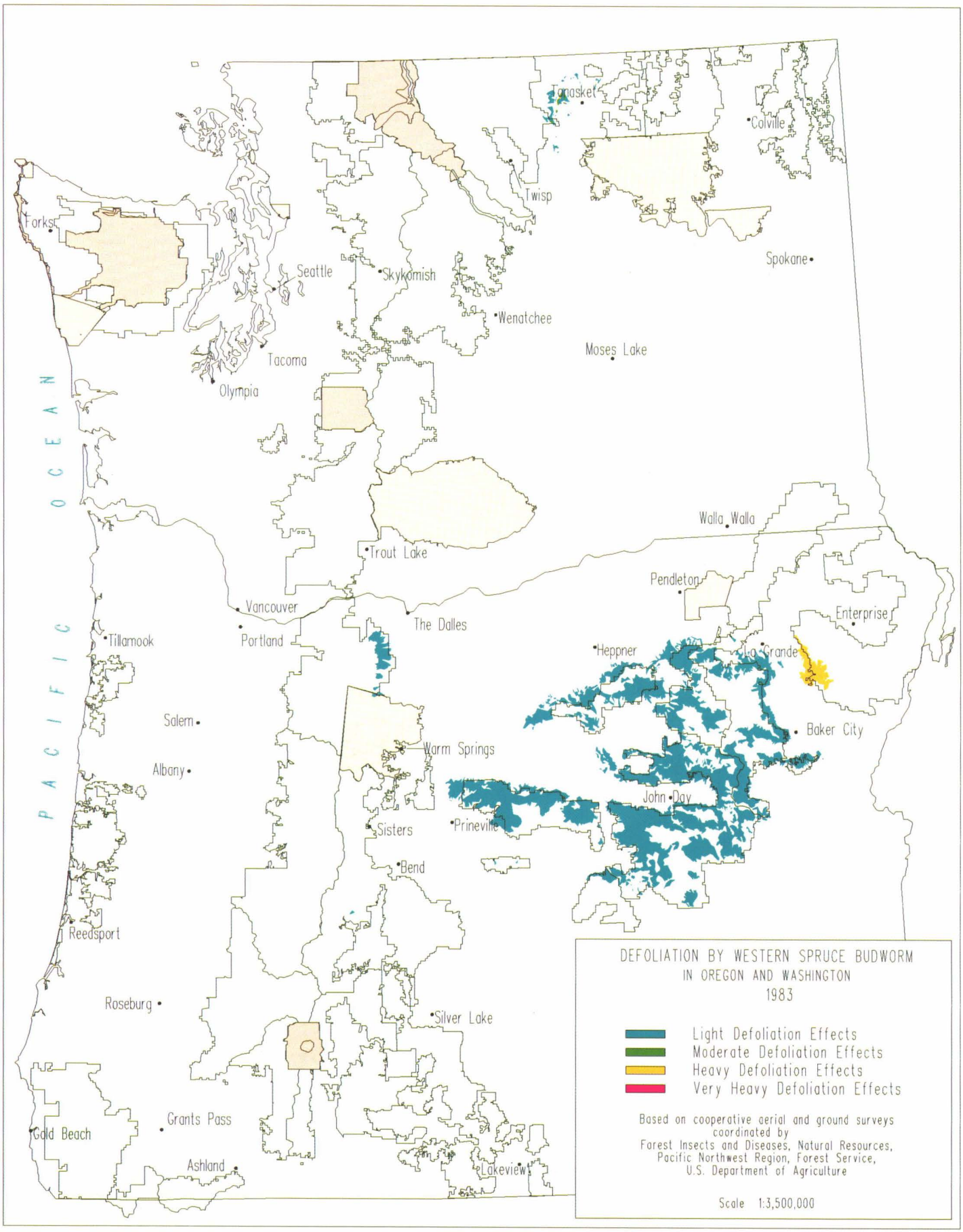
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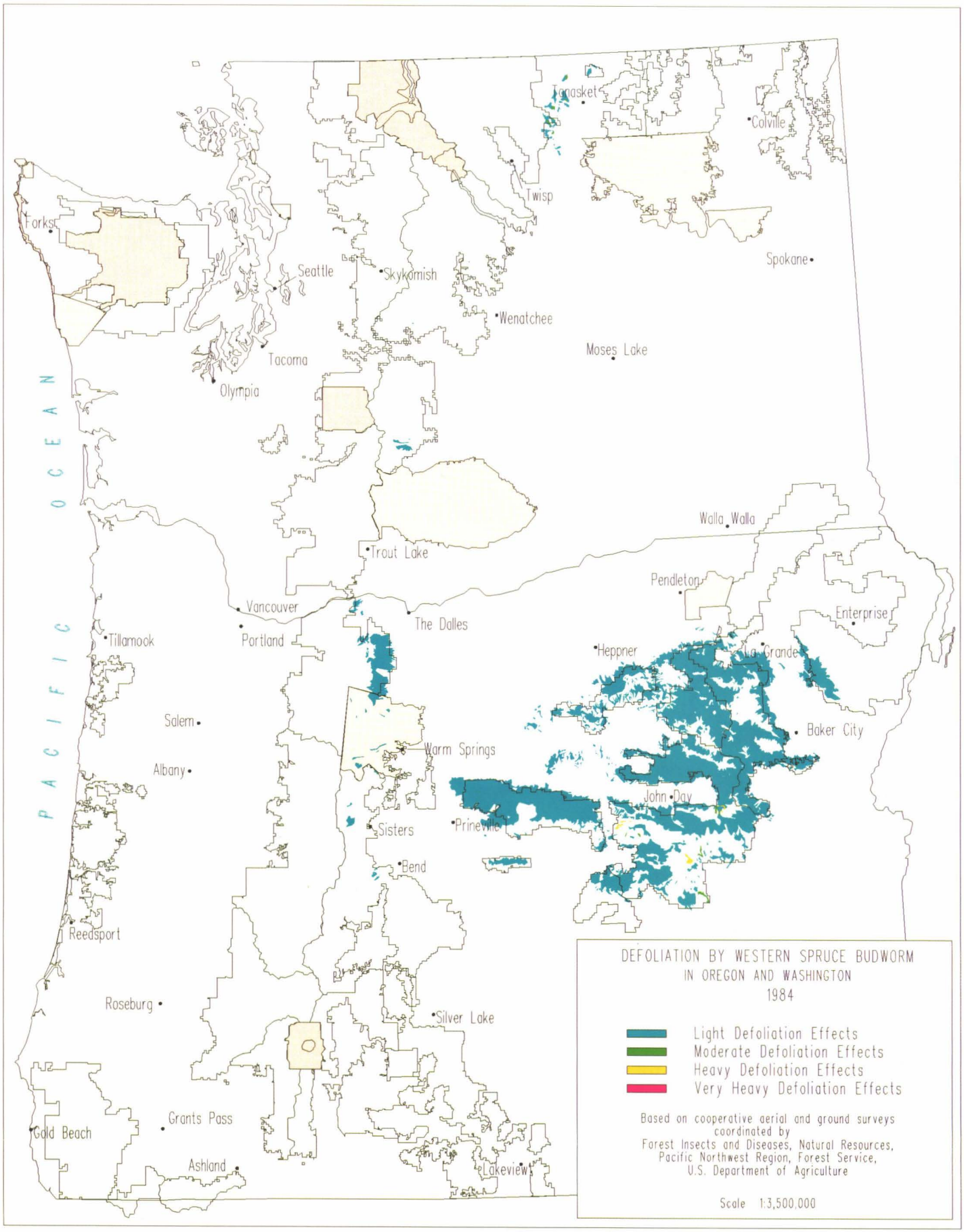
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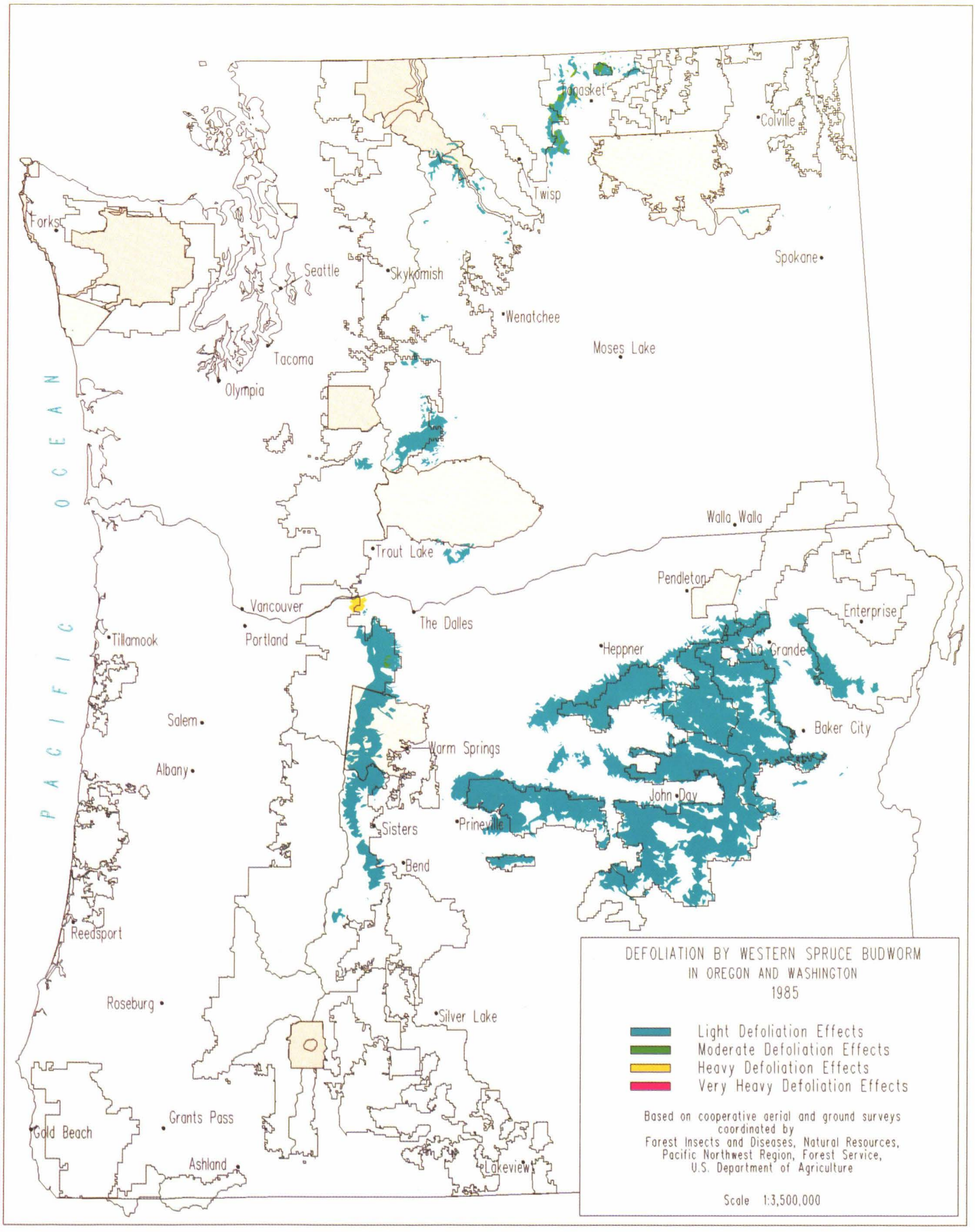
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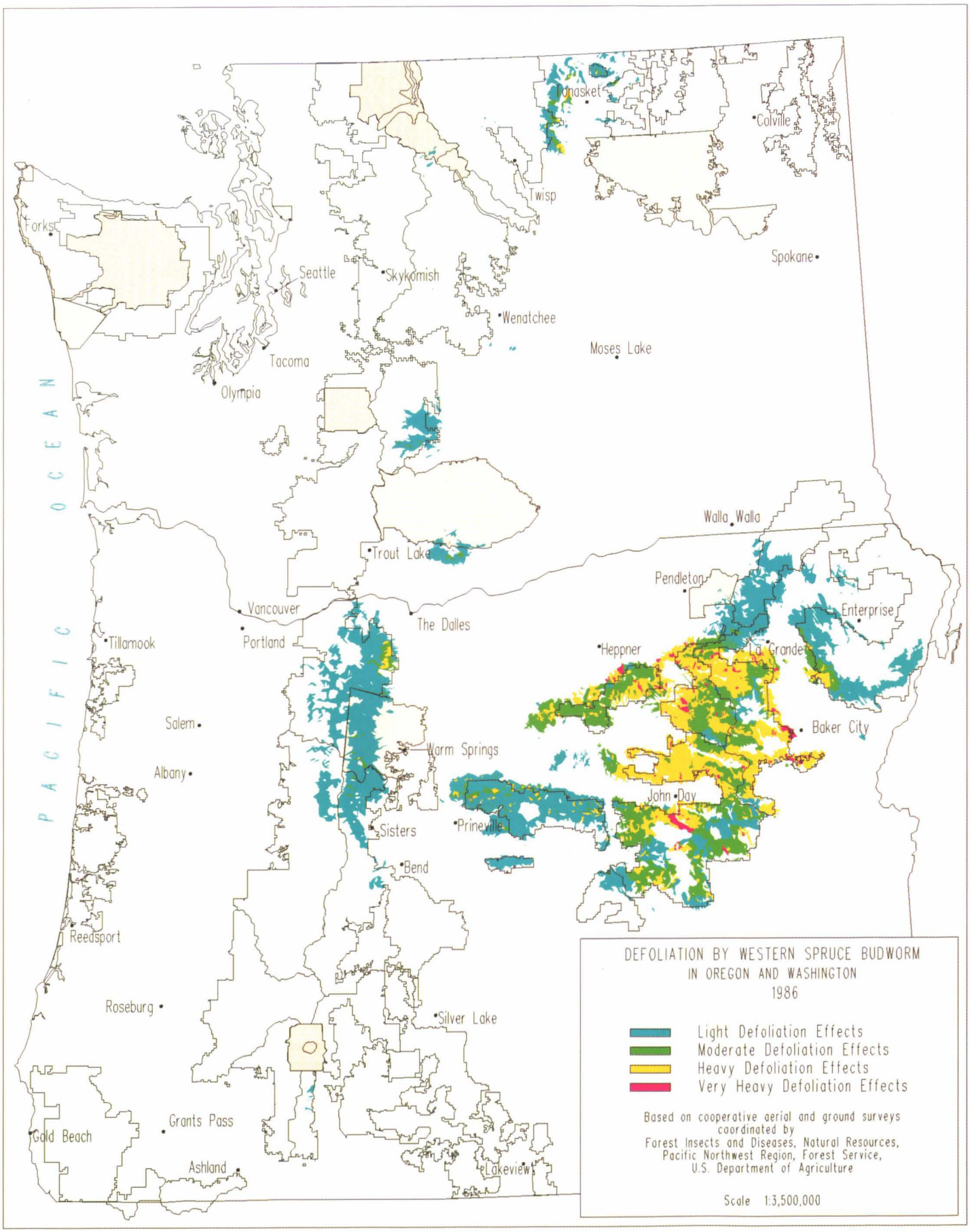
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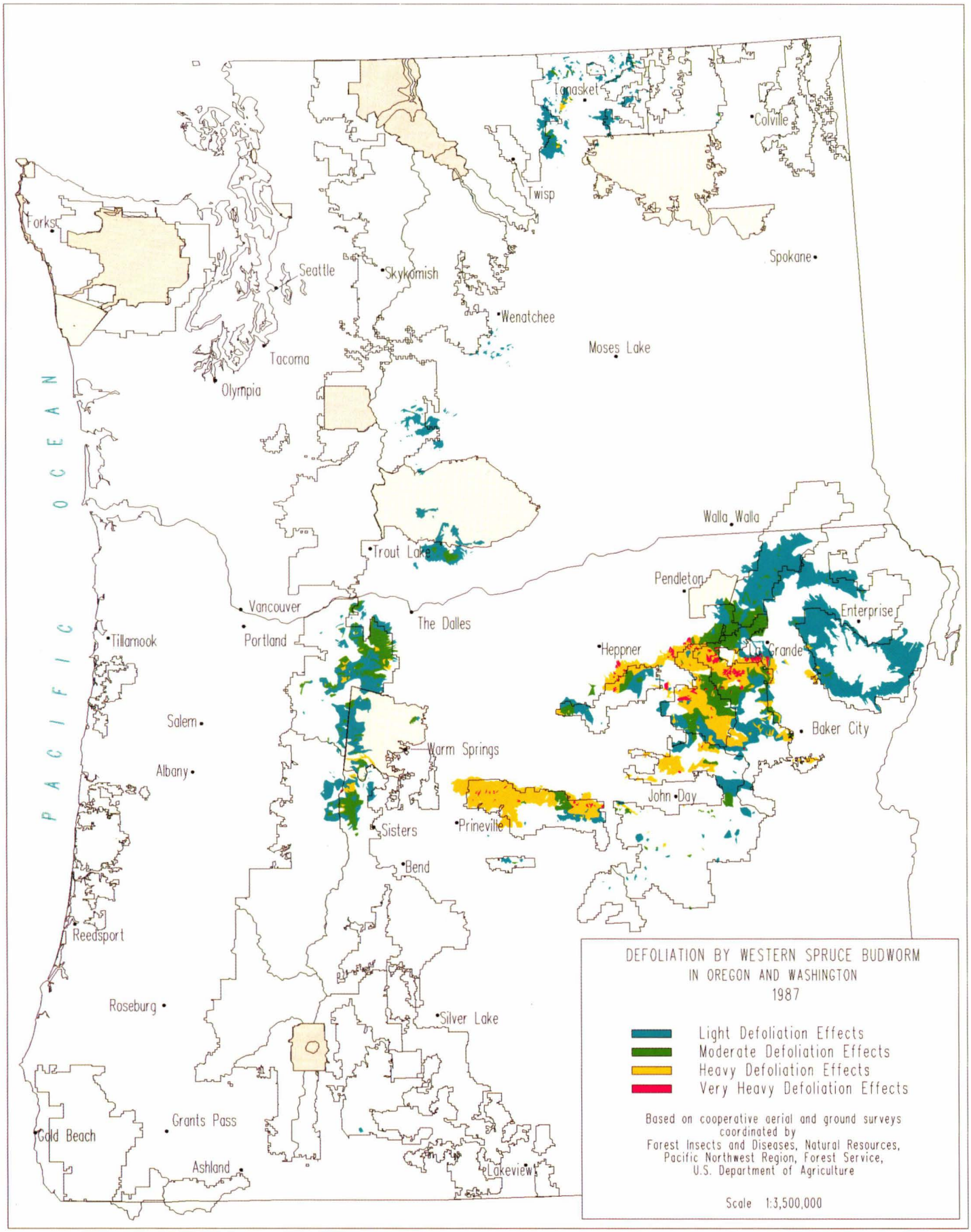
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1987
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Heavy Defoliation Effects
Very Heavy Defoliation Effects
Based on cooperative aerial and ground surveys
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Forest Insects and Diseases, Natural Resources,
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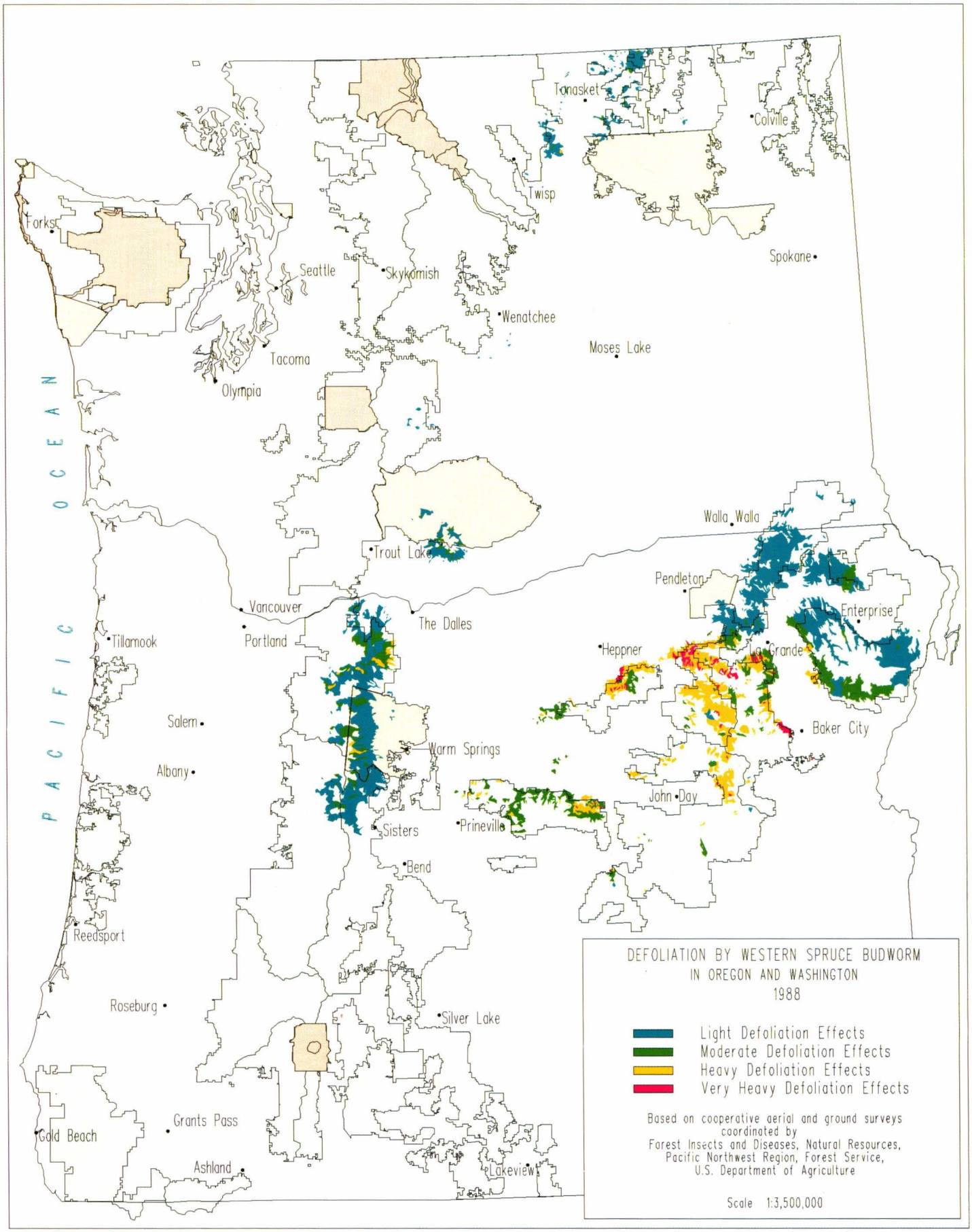
U.S. Department of Agriculture
Scale 1:3,500,000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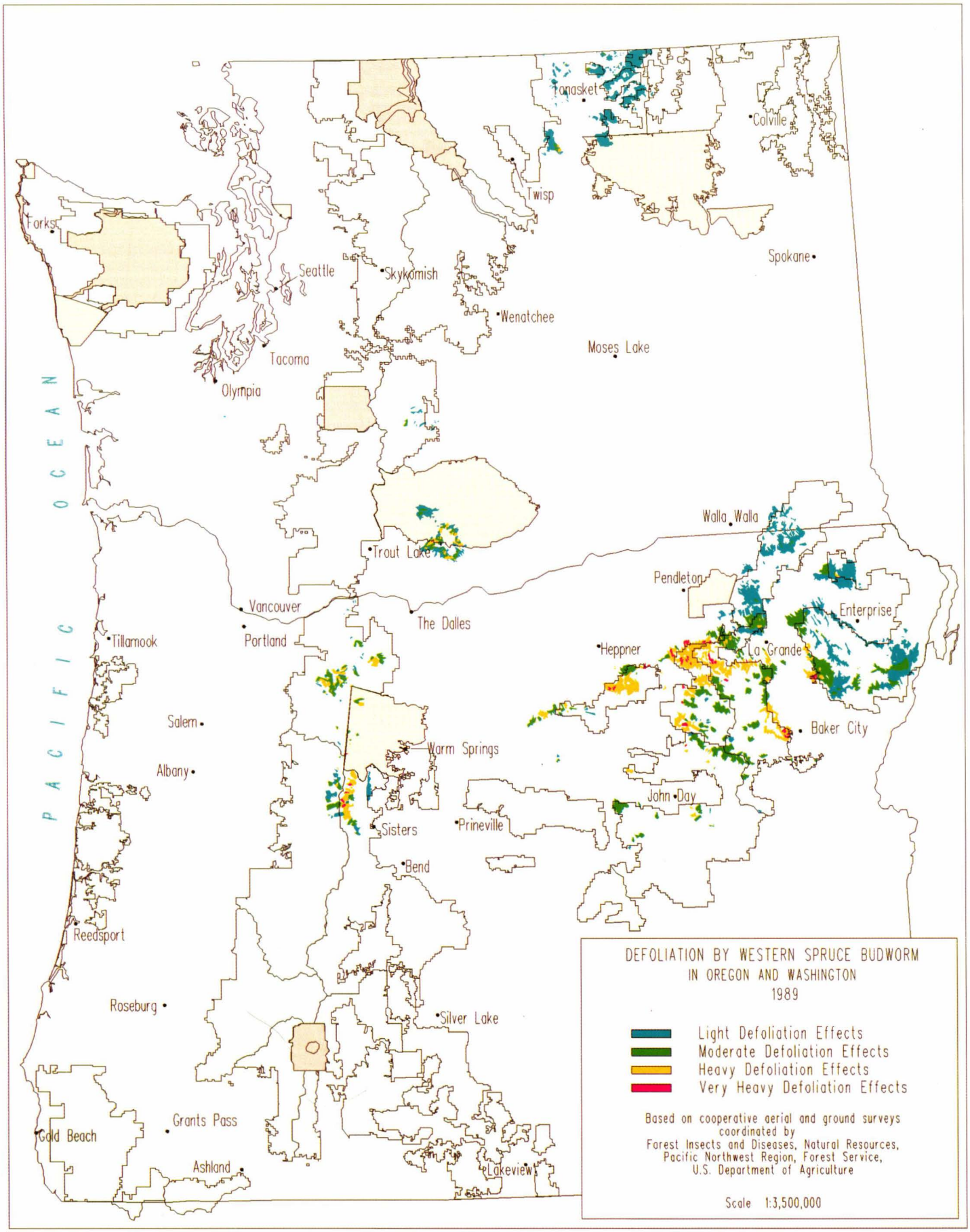
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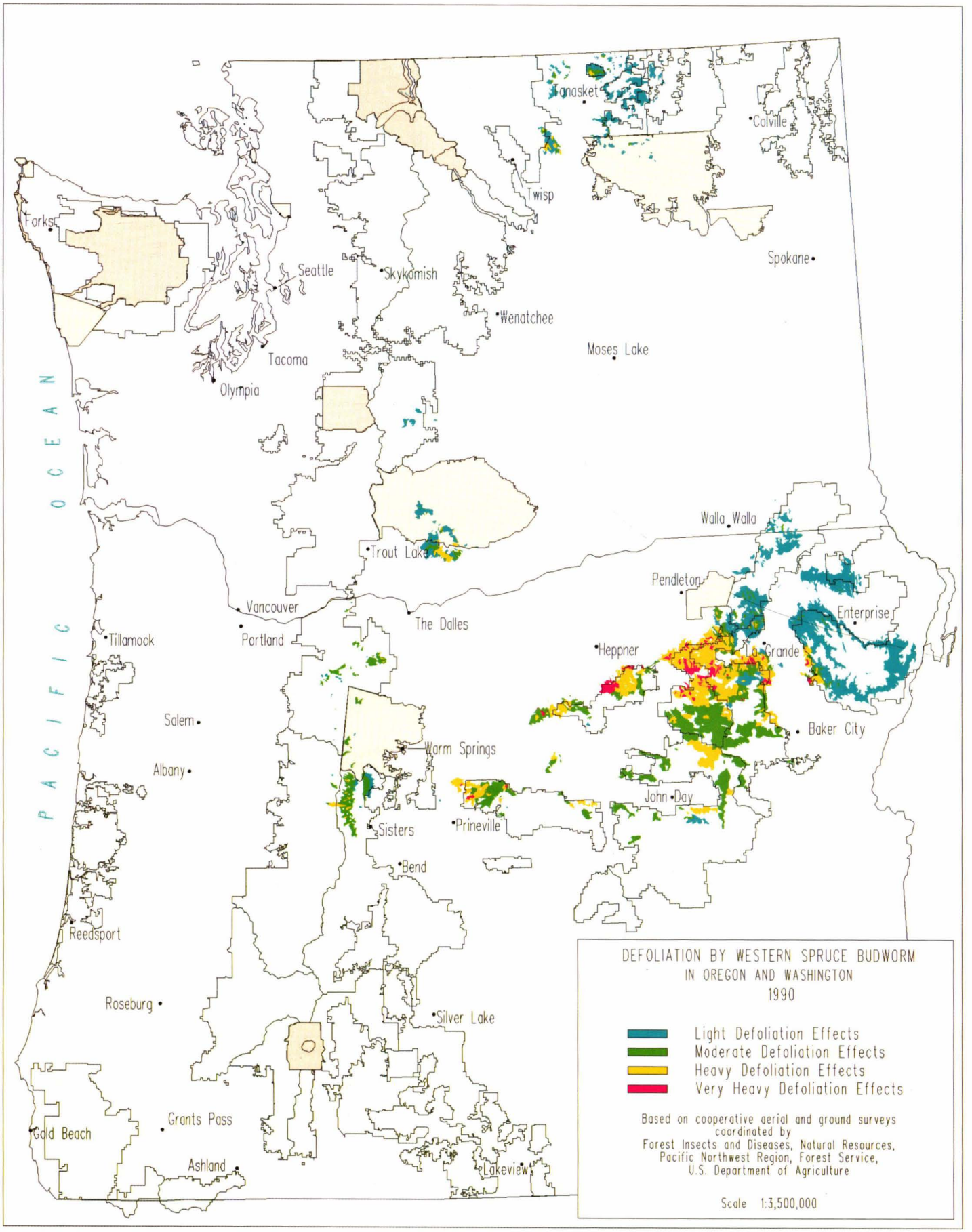
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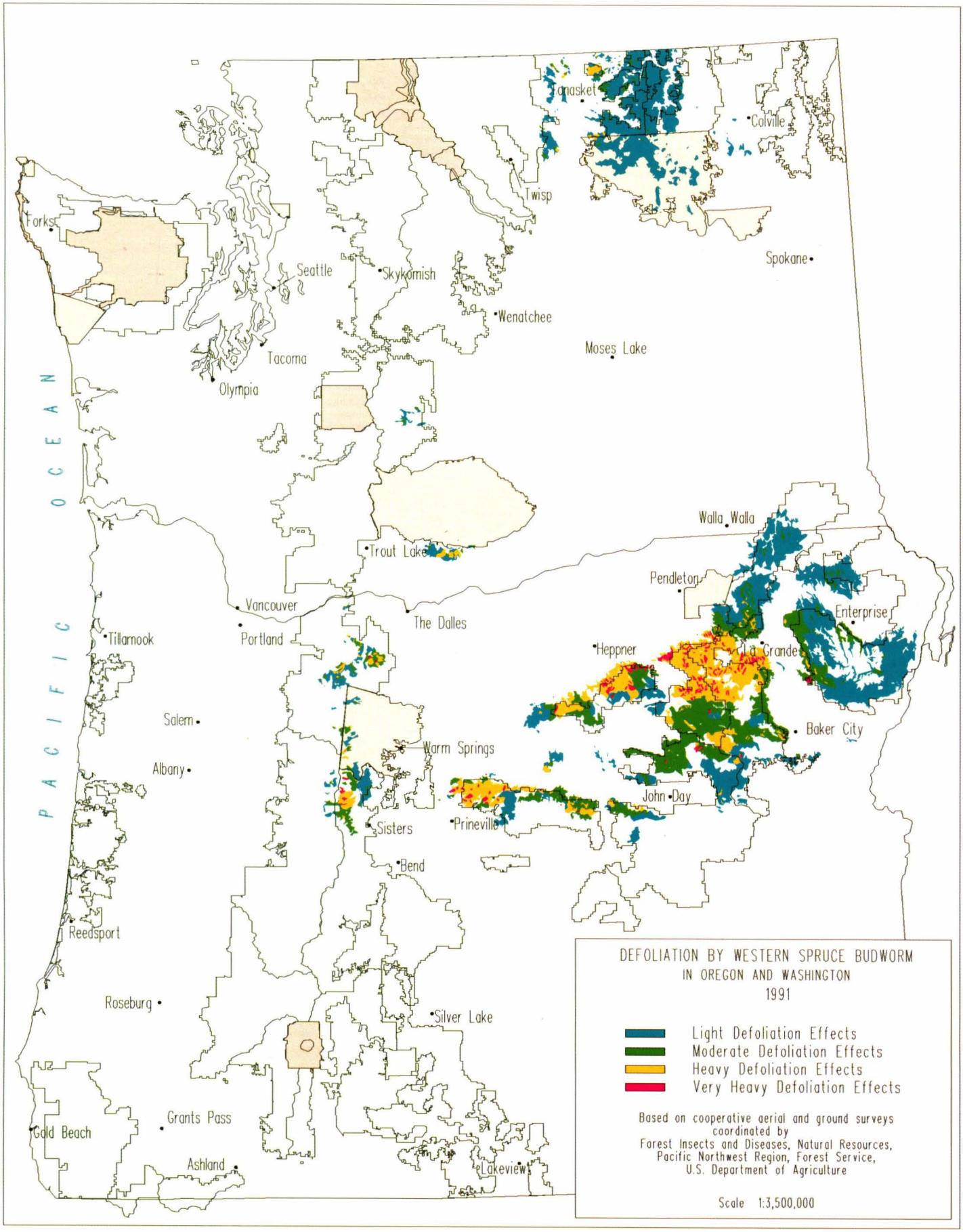
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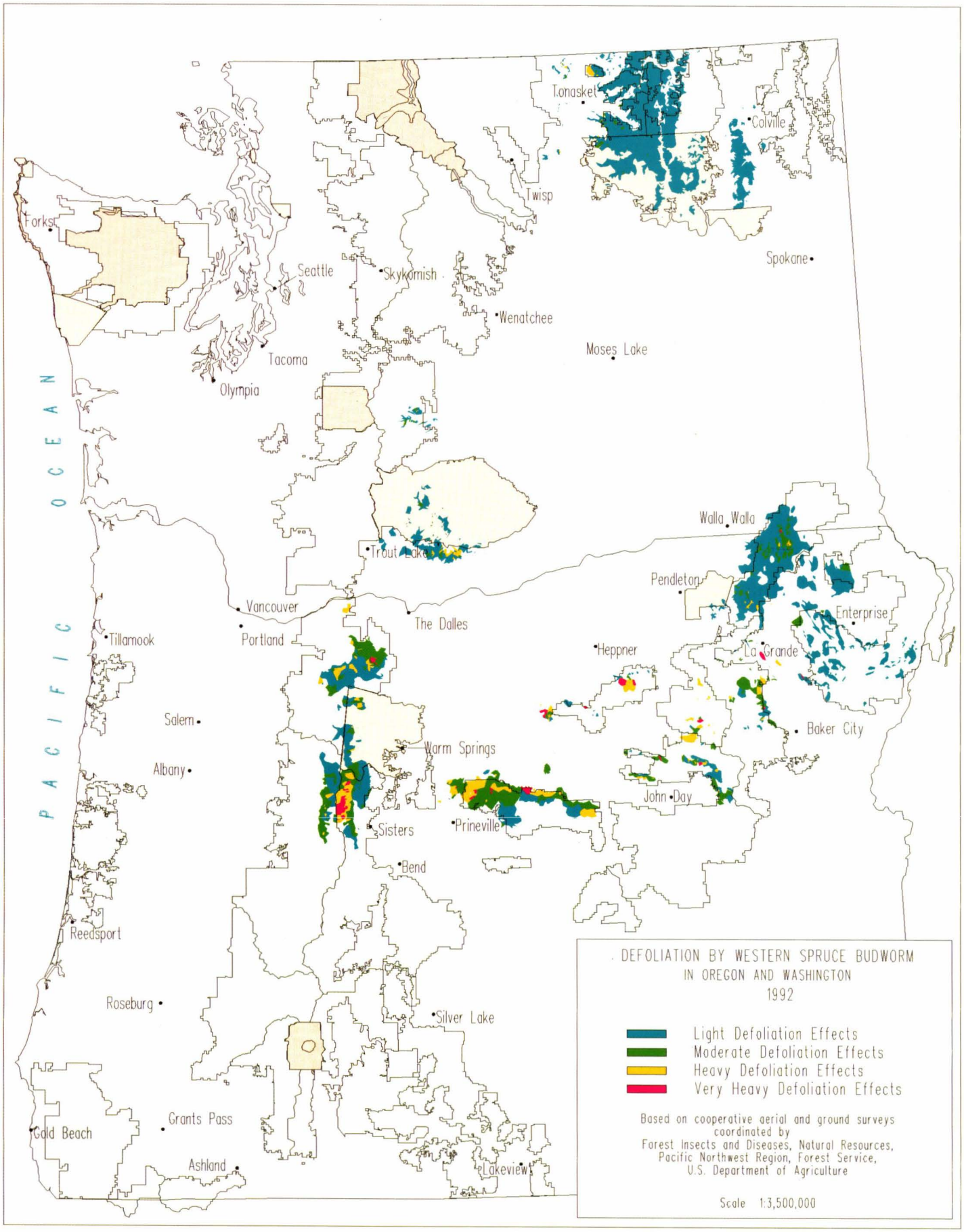
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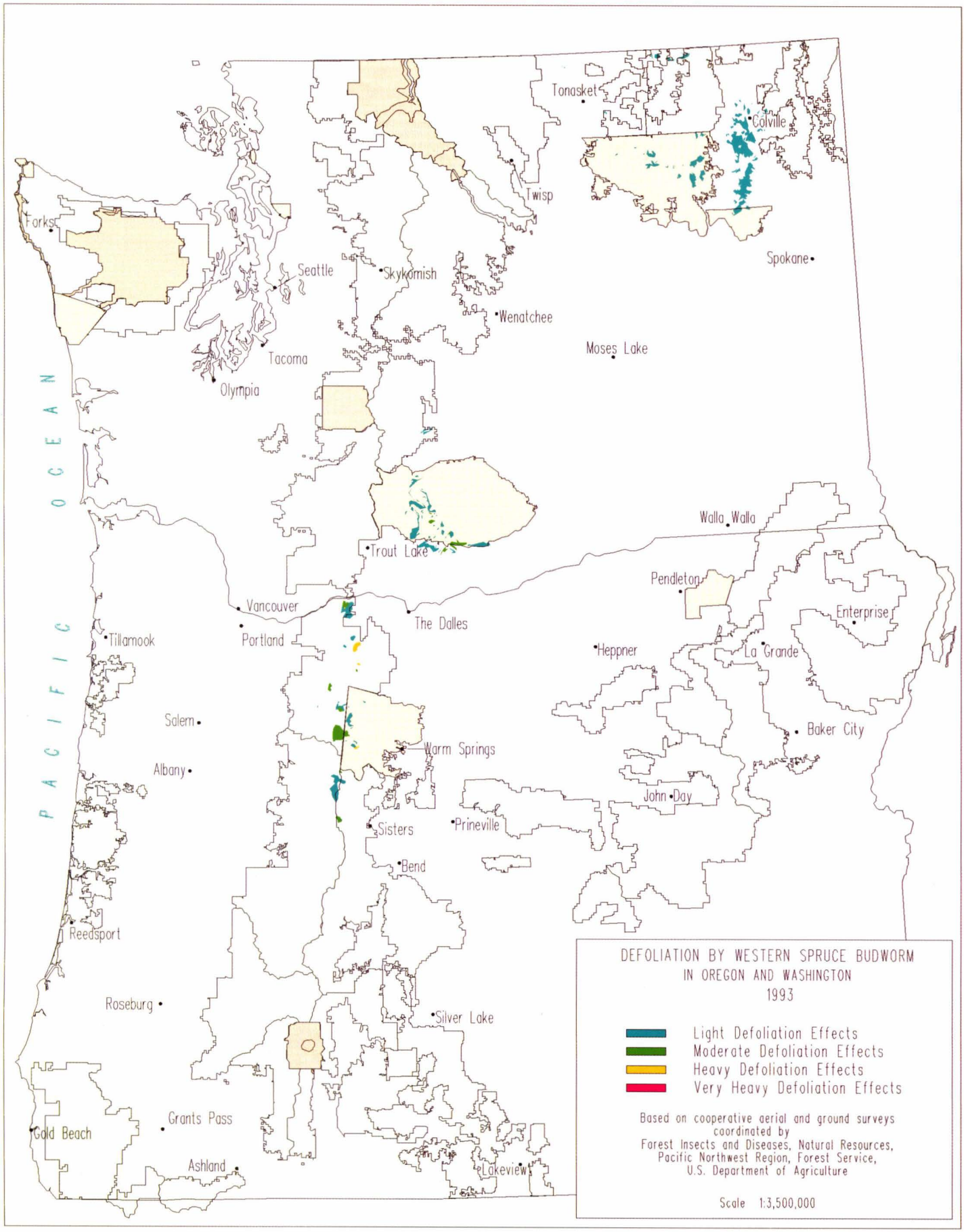
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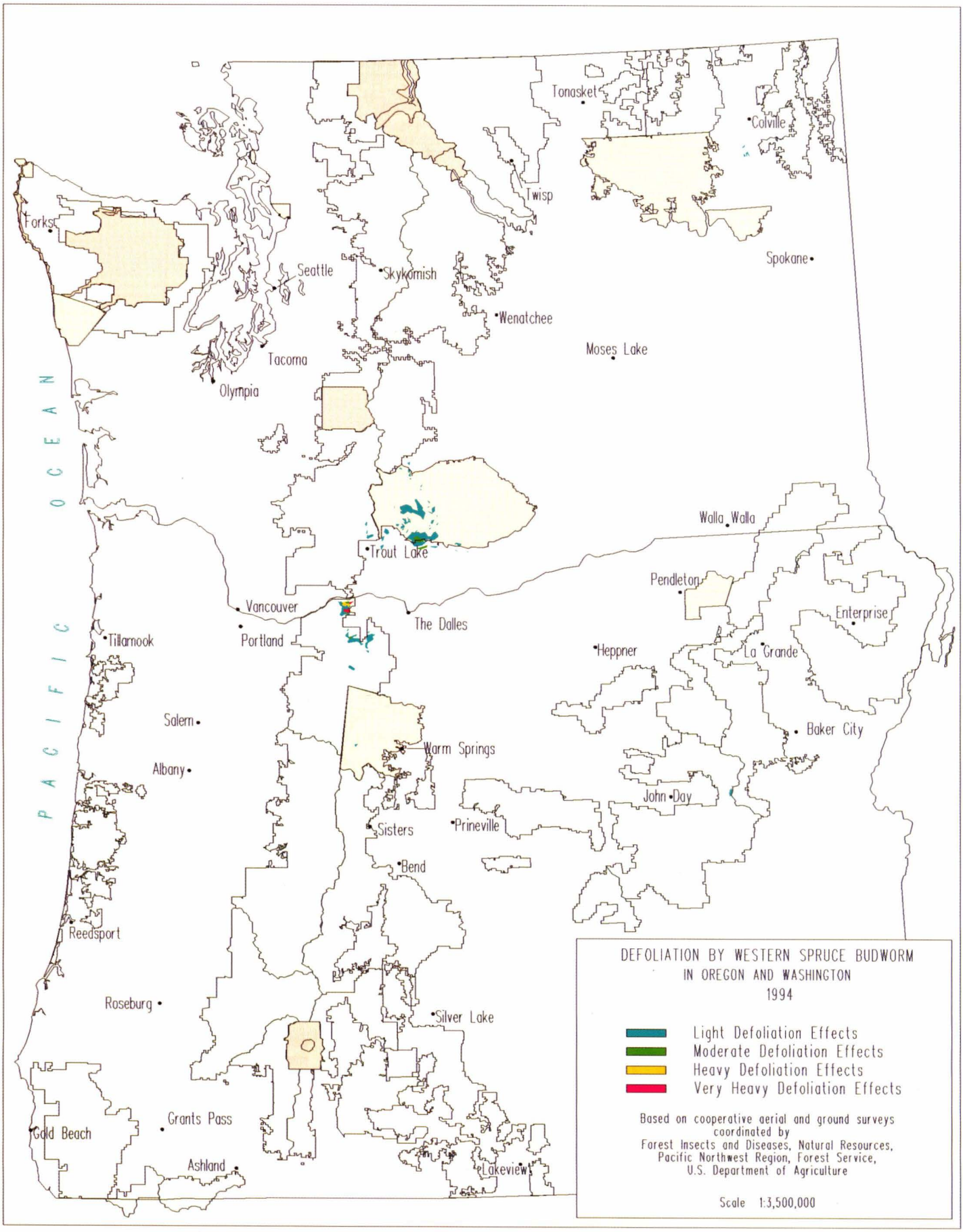
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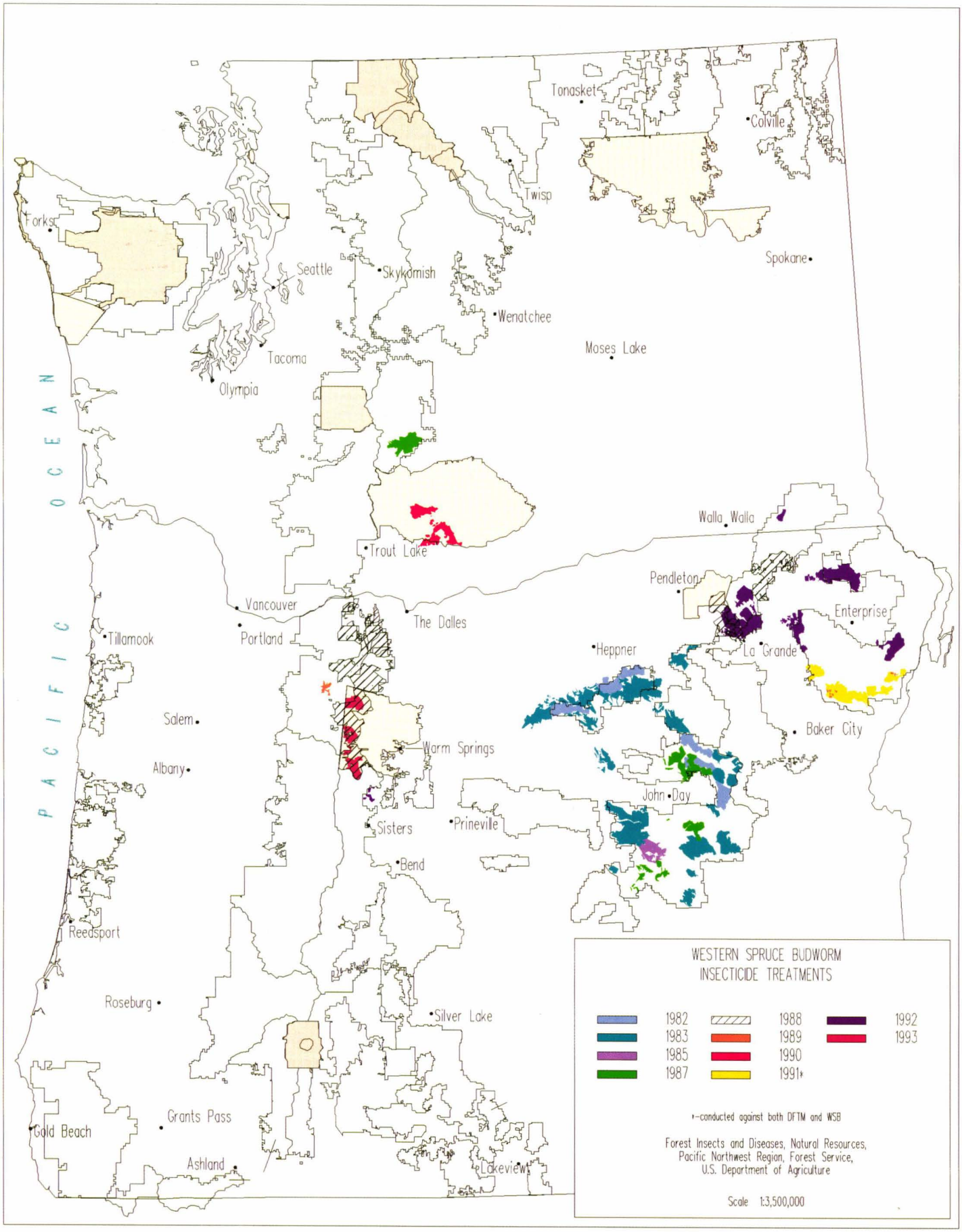
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*-conducted against both DFTM and WSB
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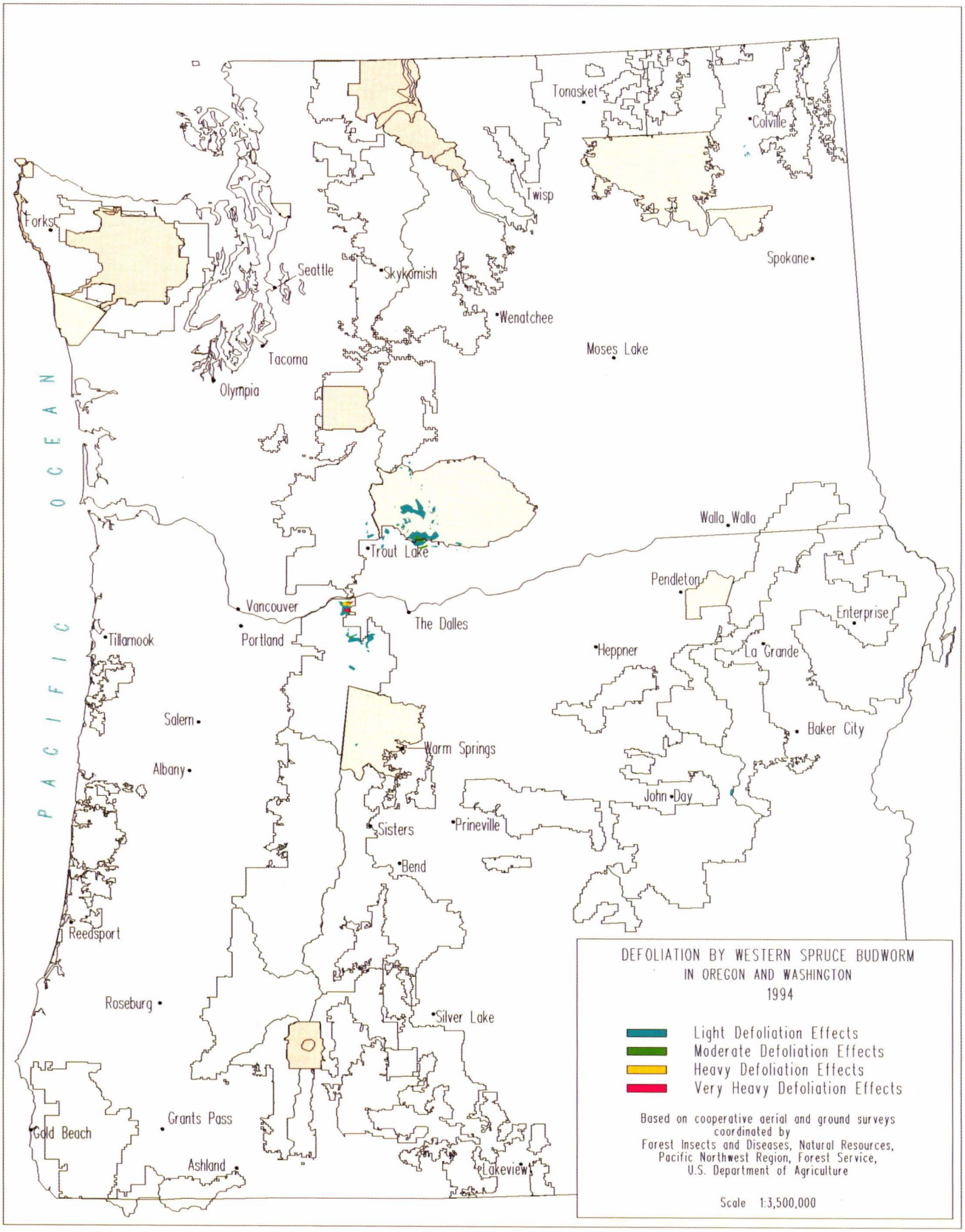
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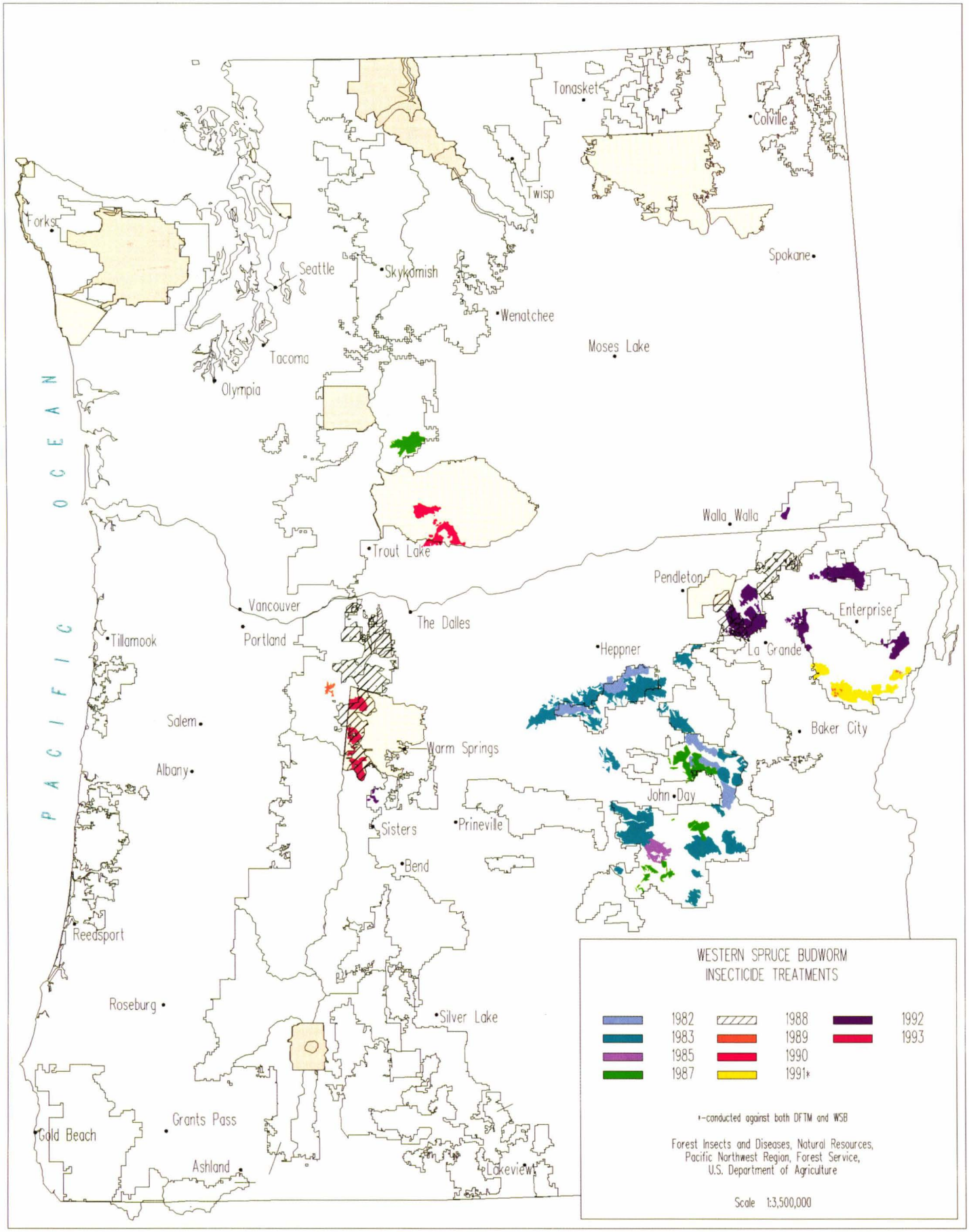
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The **Forest Service** of the U.S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the State and private owners, and management of the National Forests and National Grasslands, it strives – as directed by Congress – to provide increasingly greater service to a growing Nation.

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Pacific Northwest Region
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Portland, OR 97208-3623